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National Bureau of Standards Report

8664

Development of a Stable Ultraviolet Source and Techniques for Accurate Radiometry

Annual Summary Report

January 1, 1964 - December 31, 1964

by

Henry J. Kostkowski
Charles R. Yokley
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FACILITY FORM 602	N65-23528	N65-23528
	(ACCESSION NUMBER)	(THRU)
	32	1
	(PAGES)	(CODE)
	CW62473	11
	(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

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Microfiche (MF) 50¢

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tested as a source in ultraviolet radiometry. A paper giving the arc design, stabilizing and operating techniques and typical spectral radiance calibrations from 2200 A to 7000 A was presented at the International Symposium on Solar Radiation Simulation in Los Angeles, California, January 1965. A copy of this paper (Appendix A) is included in this report and a more extensive paper is being prepared.

An attempt will be made during 1965 to develop a small portable model of the high pressure plasma arc which can be set up and used without extensive special laboratory equipment and facilities. It is expected that such an arc could be manufactured commercially and calibrated in terms of spectral radiance at NBS down to 2000 A.

3. Standards and Techniques for Accurate Radiometry.

The measurement of optical radiation is one of the least accurate physical measurements capable of being made today. For example, standard strip lamps calibrated for spectral radiance at NBS in recent years have had uncertainties as large as 3% at 2.6 μ and 8% at 2500 A. An effort to improve this situation has been underway at NBS since about 1961. During the past year techniques and instrumentation for the more accurate calibration of spectral radiance standards were largely completed. Tungsten strip lamps can now be calibrated down to 2000 A and the uncertainty of the calibration at wavelengths between 2500 A and 8500 A reduced about a factor of 5. A description of the spectroradiometer and associated equipment developed for this purpose is given in Appendix B. A detailed paper covering this work will be available later in 1965.

Development of a Stable Ultraviolet Source
and Techniques for Accurate Radiometry

1. Objective. The objectives of this project were three-fold.

- a. To develop and investigate a high pressure plasma arc as a stable source of high ultraviolet radiance.
- b. To develop and investigate techniques for the accurate measurement of spectral radiance.
- c. To consult at NASA installations on fundamental problems relative to the measurement of radiation.

2. A Stable Arc Source of High Ultraviolet Radiance.

There is a need in ultra-violet radiometry for a stable source with significantly greater radiance than a tungsten strip lamp. At 2200 A a tungsten strip lamp has a maximum spectral radiance of about $36 \text{ watts cm}^{-3} \text{ ster}^{-1}$ as compared to about $28 \times 10^4 \text{ watts cm}^{-3} \text{ ster}^{-1}$ at 6550 A. This large decrease in the ultraviolet produces a low signal to noise ratio and also is the source of troublesome scattered light. A 20 atmosphere 50 ampere argon arc has a spectral radiance at 2200 A of about 3×10^4 that of the strip lamp but at 6500 A has a radiance only about ten times that of the strip. Thus the signal to noise ratio is increased and the scattered light reduced significantly in the ultraviolet with the argon arc.

A high pressure plasma arc exhibiting radiance temperatures of about 5000 °K at 2200 A and a reproducibility in spectral radiance of about 1% over a period of several hours has been developed and

During 1965, investigation of some of the small systematic errors in the spectroradiometer and associated apparatus will continue. The spectral radiance of the low current carbon arc will be determined, and the spectroradiometer wavelength range will be extended to 2.5 microns.

4. Consulting

During the past year close technical contact was maintained with the radiometry work of a number of NASA laboratories. Several days were spent in Mr. Eric Laue's laboratory at the Jet Propulsion Laboratory and in Mr. J. Pollack's laboratory at the Lewis Space Flight Center. A detailed discussion on the measurement of spectral irradiance in solar simulators was held with a delegation from Langley Field, and a special symposium on radiation standards was held at NBS for NASA representatives. It is believed that these various contacts have been beneficial and will help lead to an earlier solution of NASA problems involving the measurement of optical radiation.

APPENDIX A

"A Stable Arc Source of High Ultraviolet Radiance"

C. R. Yokley
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A high pressure argon arc with an intense continuum has been developed as a possible source in ultraviolet radiometry. The wall-stabilized, continuously operating arc exhibits radiance temperatures of about 5000 °K at 2400 Å. Typical operating conditions are currents from 50 to 100 amperes and pressures from 5 to 25 atmospheres. Reproducibility of spectral radiance calibrations is about 3% when argon flow, arc current, and chamber pressure are regulated within prescribed limits. Short term reproducibility over a period of several hours is about 1% in spectral radiance. The spectral radiance is approximately proportional to the square root of the pressure with an upper stability limit of 375 psia for 50 ampere arcs. The arc design, stabilizing and operating techniques along with typical spectral radiance calibrations from 2200 Å to 7000 Å is given.

N65-23527

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23527

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AUTHOR

1.0 Introduction

At the present time, there is a need for a high intensity ultraviolet radiation source which is stable and reproducible. Such a source has main application as a reference, but also has application in the fields of solar simulation, heat transfer, plasma physics, irradiated materials, and chemical photolysis.

In view of the fact that there are no commercial sources available which produce stable reproducible ultraviolet radiation of the desired magnitude, several laboratory designs of high-pressure argon sources were constructed and investigated. The radiation characteristics of a satisfactory design of such an arc source which exhibits high spectral radiance of good stability and reproducibility have been evaluated. The term stability as used here means that the signal to noise ratio of the observed radiation is 100 or better, and that the drift of the average value of this radiation is less than 1% during the several minutes required for the measurement.

2.0 Apparatus

2.1 The Arc-Source

The source, shown schematically in Figure 1, is essentially a stack of four electrically insulated elements which comprise the wall stabilizing geometry. The arc channel through each is 0.125 inch in diameter, and the separation between adjacent elements is 0.1 inch. A cross section of one of the stabilizing elements used adjacent to the observation zone of the arc is given in Figure 2. The cooling

water flow in all four of the elements is the same although the method of holding the copper insert is different for those near the electrodes. The over-all design of the high-pressure source is such that the pressure vessel, arc stabilizing elements, cooling water channels, and viewing windows form one integral unit. The assembly measures about 16 inches in height and 9 inches in diameter.

Provision for argon injection between the arc stabilizing elements determines the flow characteristics of the source, and in part the upper stability limit for high pressure operation. There is an argon exhaust port between each pair of elements except those forming the arc observation zone. No intentional flow exists in this zone.

The direction of flow appears to be important only in the electrode chambers and tangential argon injection is used in the space between the electrode tip and the adjacent wall stabilizing element. The high-pressure argon is supplied to the arc by the system as described in Figure 3.

The main electrodes for the arc are located at the ends of the assembly, and the total arc current is conducted through these electrodes. The arc assembly is operated with the long axis of the arc vertical and a hollow, water cooled cathode at the top. A 1/8 inch diameter hole through the center of this electrode permits insertion and withdrawal of an arc starting rod.

The entire assembly is mounted on an optical bench in such a manner that all necessary translations and rotations for proper

alignment with the monochromator can be carried out with micrometer precision (0.001"). The target area (described later) of the observed arc is located between the two centrally located arc stabilizing elements. The radiation measured passes through a water-cooled quartz window. The observable radiating arc volume is geometrically determined by the 1/8 inch diameter holes in the stabilizing elements and the 0.1 inch separation between them. The internal construction is such that the limiting solid angle for a centrally located point source is $f/15$.

2.2 Control Equipment

Stable, reproducible performance of this source requires control of the total pressure, the argon mass flow in the chambers, and the arc current. The arc current is maintained constant to within 0.06 ampere by using a series regulating element connected as shown in Figure 4. This series element is a group of thirty power transistors (Q_1-Q_{30}) connected in parallel. Essentially, the voltage drop across the series unit is varied in a manner so as to oppose current changes. The required variation is determined by an error signal which is the difference between the shunt and reference voltages. This signal, properly amplified in magnitude and polarity, controls the series unit.

For a given spacing of the stabilizing units and main electrodes, there is an upper total pressure limit for an arbitrarily chosen set of argon mass flow rates. These flows are determined experimentally for the maximum pressure to be used by observing the noise on a recorded radiation signal and by making adjustments (primarily at the cathode) until the stability as defined above is obtained. Once these flow rates

have been determined, they need not be changed for any other total pressure less than that selected for the maximum.

The gas flow system as described permits regulation of the total pressure to within $1/4$ psia over the whole range of pressures used. The total pressure is determined by the setting of regulator R_2 and the individual exit flows from the chambers are adjusted by means of valves (V_1-V_4) and regulator R_3 . These flows are kept constant to within about 2% of the original value by occasional manual adjustments.

2.3 Spectral Radiance Measuring Equipment

The optical-electronic measuring system is shown schematically in Figure 5. Basically, it consists of an Ebert-type monochromator and provision for imaging the source on the entrance slit. As measurements are made in the ultraviolet and over a wide spectral range, first surface aluminum mirrors are used to reduce the absorption and to eliminate the necessity of refocussing. The system includes provision for the insertion of suitable filters (F_1F_2) in the optical path to eliminate the second and third order spectra and to attenuate the arc radiation so that the photomultiplier currents will not be too high (1×10^{-7} ampere maximum). The photomultiplier that is primarily used is of the "solar-blind" type and is used to cut down the effect of scattered light upon the signal when measurements are being made in the ultraviolet. When the measurements are being made at 2500 Å, the resultant contribution of the scattered light to the true signal is about 1%.

3.0 Procedure

The reproducibility of the spectral radiance of the source involves radiation from a particular geometrically located volume within the arc when all of the above mentioned operating conditions are held constant to within the prescribed limits. The target area as determined from the magnification and the entrance slit dimensions is 0.022 inch high and 0.012 inch wide. The arc is positioned, relative to the monochromator, so that this area is centered between the stabilizing elements in the vertical sense, and at the position giving the maximum spectral radiance reading horizontally. The horizontal spectral radiance profile is such that a movement of the arc of about 0.005 inch either side of the above position causes a 1% decrease in the spectral radiance measurement. This profile along with the size of the target area determines the sensitivity of the measurements to the positioning of the arc. Since both the calibration source and the arc have to be moved during the course of the measurements, the alignment of the target area of both with respect to the monochromator is reproduced as nearly as possible (0.001 in.).

3.2 Calibration

In order to make the measurements independent of the optical elements, an external reference of known spectral radiance is substituted for the arc after each experiment. This reference source is a tungsten ribbon-filament lamp and has a quartz window. The lamp was calibrated in terms of average spectral radiance over the target area in the Temperature Physics Section of

the National Bureau of Standards [1] and, when operated at a prescribed current, has a filament temperature of about 3000 K (true). The photoelectric measurements are dependent upon the fatigue characteristics of the photomultiplier, the effects of which are minimized by limiting the output current to 0.1 microampere and, additionally, by exposing the photomultiplier to light for a one hour pre-fatigue program at an output current of 0.2 microampere. For measurements made in the ultraviolet, stripchart recordings are taken at 100 Å intervals by changing the wavelength setting of the monochromator. At each wavelength setting used, the photomultiplier current is continuously recorded and the measurements of stability, scattered light and signal to noise ratio are carried out.

As soon as a set of spectral measurements has been completed, the calibrated strip lamp is substituted for the arc, the filter (F_1) removed and calibration performed. The data from the arc measurements, the strip lamp calibration, and the filter transmittances permit calculation of the absolute spectral radiance of the high-pressure arc source.

4.0 Results

4.1 Absolute Spectral Radiance

The spectral radiance characteristics for a 50 ampere arc operated at pressures of 75, 150, and 300 psia are given in Figure 6. Included is

[1] H. J. Kostkowski and R. D. Lee, Theory and Methods of Optical Pyrometry, 22-26, National Bureau of Standards Monograph 41.

the spectral radiance of pertinent blackbodies for comparative purposes. The lower curve shown is the dimensionless ratio ($R_{N\lambda}$) of the arc spectral radiance to that of the strip lamp. Spectral radiance is given in watts $\text{cm}^{-1}\text{cm}^{-2}\text{steradian}^{-1}$. The 300 psia value for the arc chamber total pressure is an upper stability limit for the arc as assembled for these experiments.

A 75 ampere arc has the spectral radiance characteristics as presented in Figure 7. At this current, a somewhat lower pressure of 225 psia is the maximum pressure permitted for assured stability of the arc. In view of the fact that the 75 ampere arc at the maximum pressure does not exhibit significantly greater spectral radiance than the 300 psia arc at 50 amperes, the latter is recommended because of the simpler power supply requirements. The voltage across the electrodes for the 50 ampere 300 psia arc is about 125 volts.

Although the spectral radiance as shown by the curves indicates radiation from a continuous source, this is the case only for wavelengths less than about 3800 Å. Above this value, these high-pressure arcs exhibit line spectrum as well as continuum. The reproducibility reported here is however based upon measurements made in the continuum only. In the ultraviolet range from 2100 Å to 3800 Å there is no observed line emission.

4.2 Reproducibility

A 300 psia 50 ampere arc has been selected as representative of one of the more useful, trouble-free arcs evaluated. Such an arc exhibits

a combination of high spectral radiance, moderate power requirements (approximately 6 kw), good stability, and good reproducibility. The data for several daily operations of the arc which show the reproducibility in terms of ratios of the spectral radiance of the arc to that of the calibrated strip lamp reference source are given in Table 1. This information does not give the arc-source reproducibility alone but includes effects contributed by the two alignments required while obtaining the data. The reproducibility stated should be taken however as that which could be expected with the actual use of such a source.

5. Conclusions

A laboratory arc-source of high spectral radiance approximating that of a 5000 °K blackbody has been developed and has been operating on a trouble-free intermittent basis for several months. The source may be used where the spectral radiance on a daily basis having a standard deviation of about 2.5% is acceptable. The source output can be varied to suit the individual requirements by changing either the total pressure or the supply current. Short term (hours) reproducibility is in the order of 1% or better. At present, the internal geometry of the unit limits the side-on exit beam to $f/15$. During typical operation, signal to noise ratios relative to the measured spectral radiance of 200 or better are observed. The source exhibits purely continuous radiation in the 2100 Å to 3800 Å wavelength range.

6. Acknowledgements

The author is indebted to Dr. H. J. Kostkowski, group leader of the High Temperature Measurements Laboratory, where the current work was performed, for many helpful discussions during the course of the work.

Captions

- Figure 1. Schematic diagram of the high pressure arc assembly.
- Figure 2. Cross section of typical water-cooled arc constricting element.
- Figure 3. Schematic diagram for the high pressure argon supply. The location of the control valves V, the regulators R, the flow-meters FM, and the pressure monitor P is indicated.
- Figure 4. Schematic diagram for the arc current regulation and power loop.
- Figure 5. Schematic diagram for the optical-electronic system for spectral radiance measurements. S is the source and W is the water-cooled quartz window. The location of the mirrors M, filters F, grating G, and photomultiplier PM is indicated.
- Figure 6. High pressure argon spectral radiance for a 50 ampere arc. The lower curve is the spectral radiance ratio of the arc to the strip lamp.
- Figure 7. High pressure argon spectral radiance for a 75 ampere arc. The lower curve is the spectral radiance ratio of the arc to the strip lamp.
- Table 1. Experimental reproducibility of the spectral radiance ratios of the arc to the strip lamp. Data is given for a 50 ampere arc operated at 300 psia.

Table 1.

Wavelength (Å)	Spectral Radiance Ratios				Mean	Standard Deviation (%)
2100	4.31×10^4	4.25×10^4	4.16×10^4	4.36×10^4	4.29×10^4	2.14
2200	3.36×10^4	3.29×10^4	3.12×10^4	3.27×10^4	3.29×10^4	2.14
2300	2.17×10^4	....	2.05×10^4	2.14×10^4	2.13×10^4	2.46
2400	1.29×10^4	....	1.24×10^4	1.27×10^4	1.28×10^4	2.12
2500	7.23×10^3	7.56×10^3	....	7.28×10^3	7.37×10^3	1.99
2600	4.34×10^3	....	4.13×10^3	4.26×10^3	4.27×10^3	2.46
2700	2.71×10^3	....	2.54×10^3	2.66×10^3	2.67×10^3	3.42
2800	1.68×10^3	1.70×10^3	1.63×10^3	1.73×10^3	1.71×10^3	2.24
2900	1.19×10^3	....	1.14×10^3	1.18×10^3	1.18×10^3	2.51
3000	8.57×10^2	....	8.36×10^2	8.54×10^2	8.51×10^2	1.16
3100	6.62×10^2	6.37×10^2	6.54×10^2	6.68×10^2	6.60×10^2	2.97

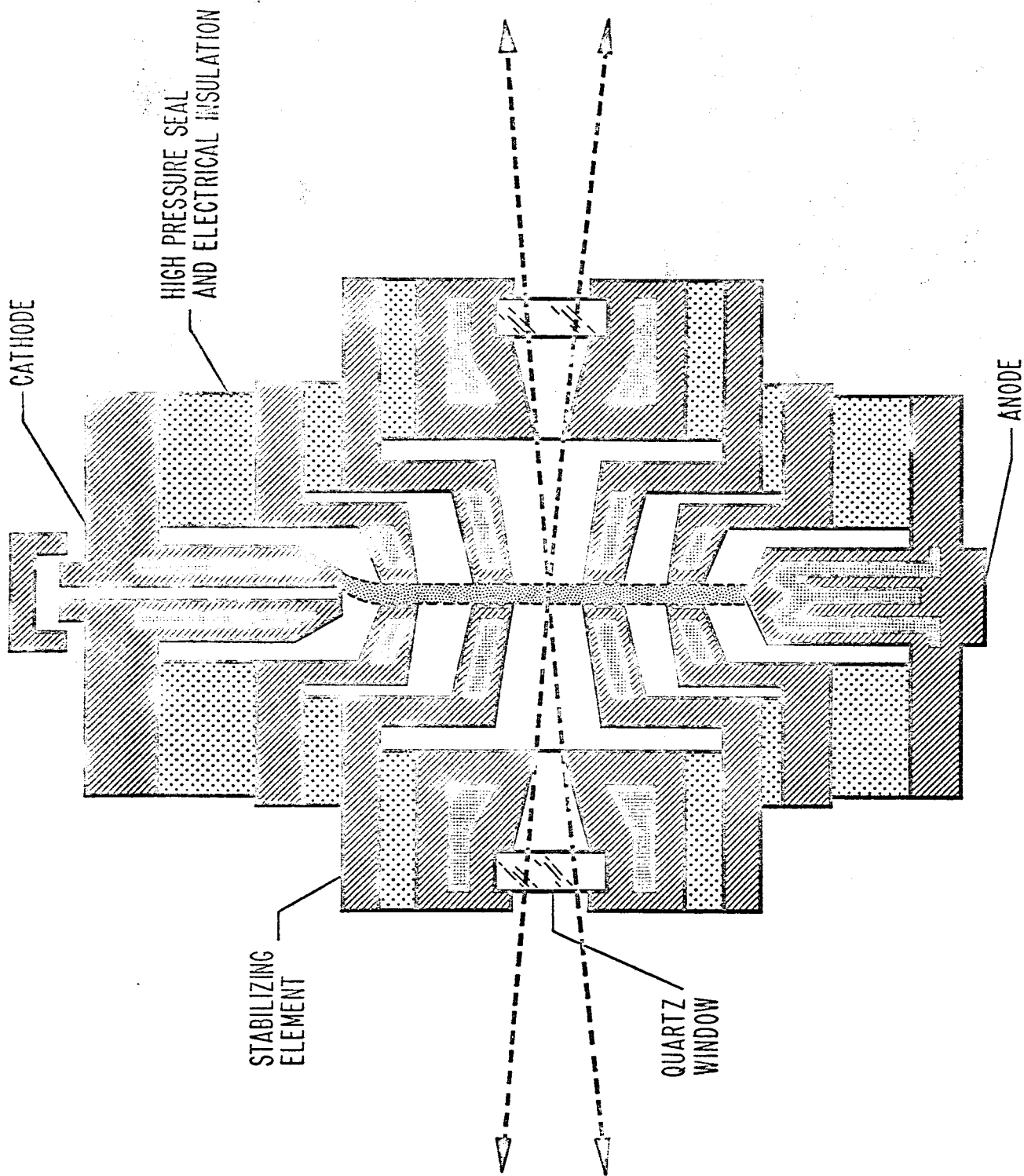


Fig. 1 Schematic diagram of the high pressure are assembly.

OBSERVATION ZONE ARC CONSTRICTING ELEMENT

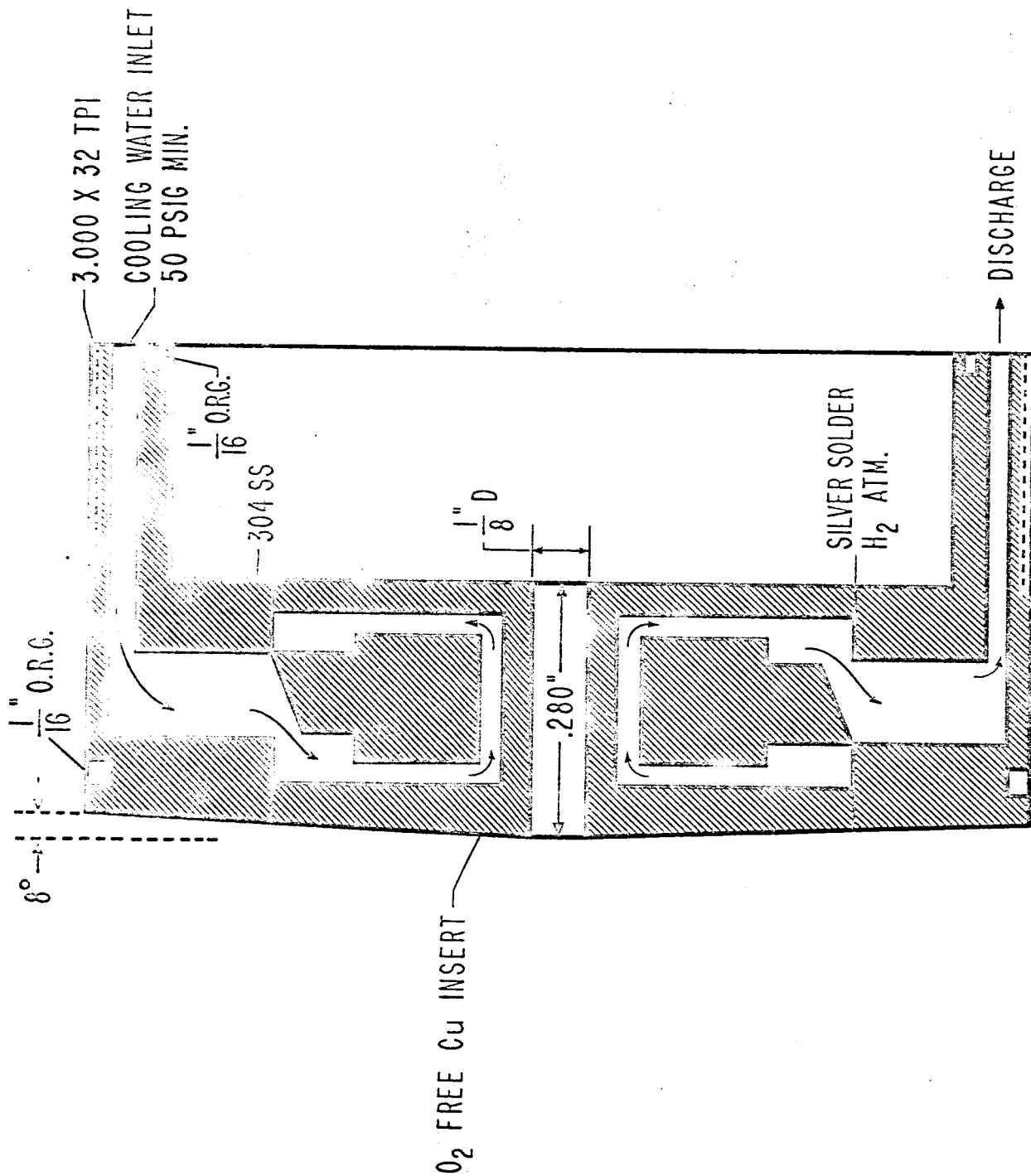


Fig. 2 Cross section of typical water-cooled arc constricting element.

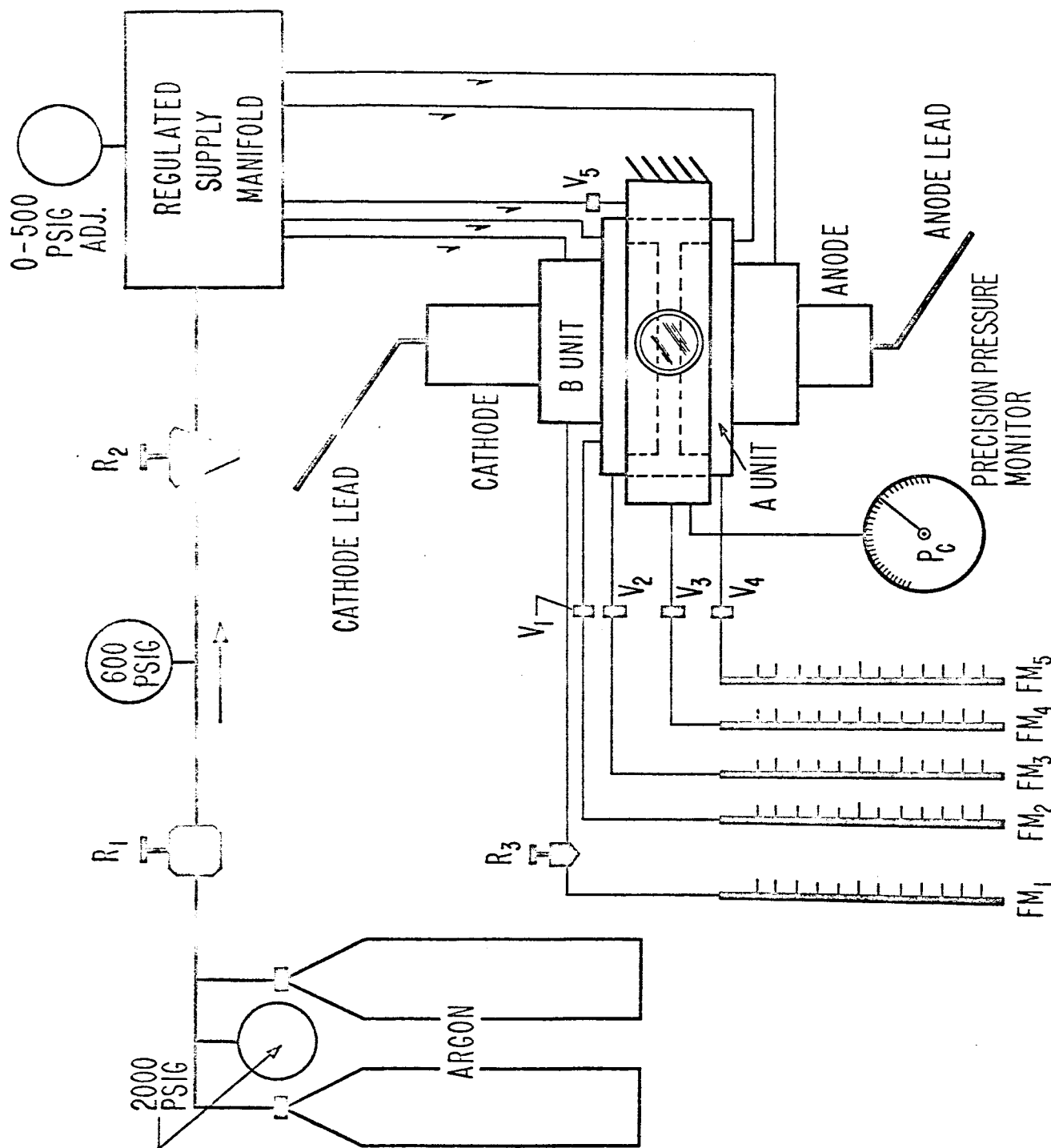


Fig. 3 Schematic diagram for the high pressure argon supply. The location of the control valves V, the regulators R, the flowmeters FM, and the pressure monitor P is indicated.

ARC CURRENT CONTROL LOOP

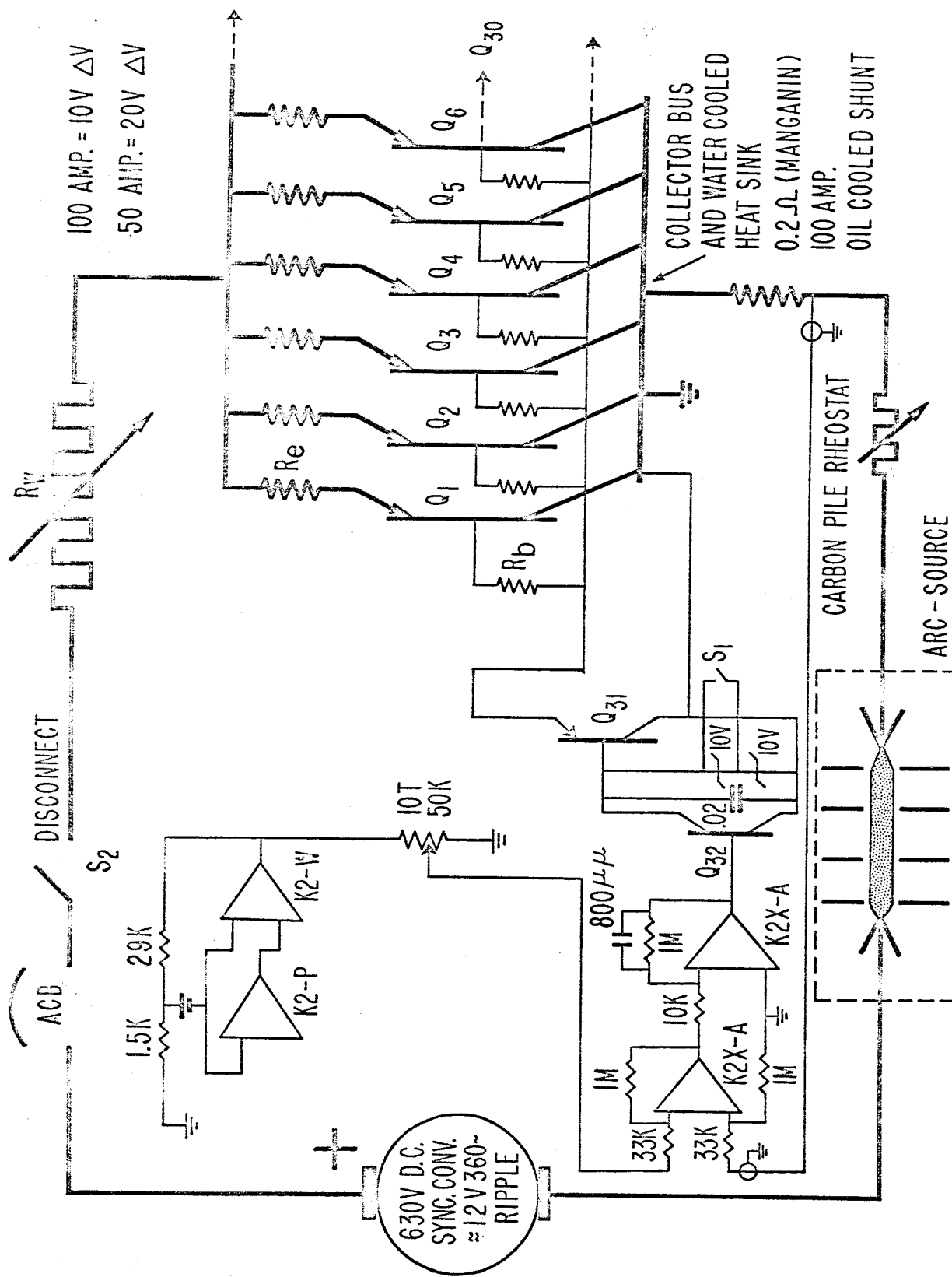


Fig. 4 Schematic diagram for the arc current regulation and power loop.

OPTICAL SCHEMATIC

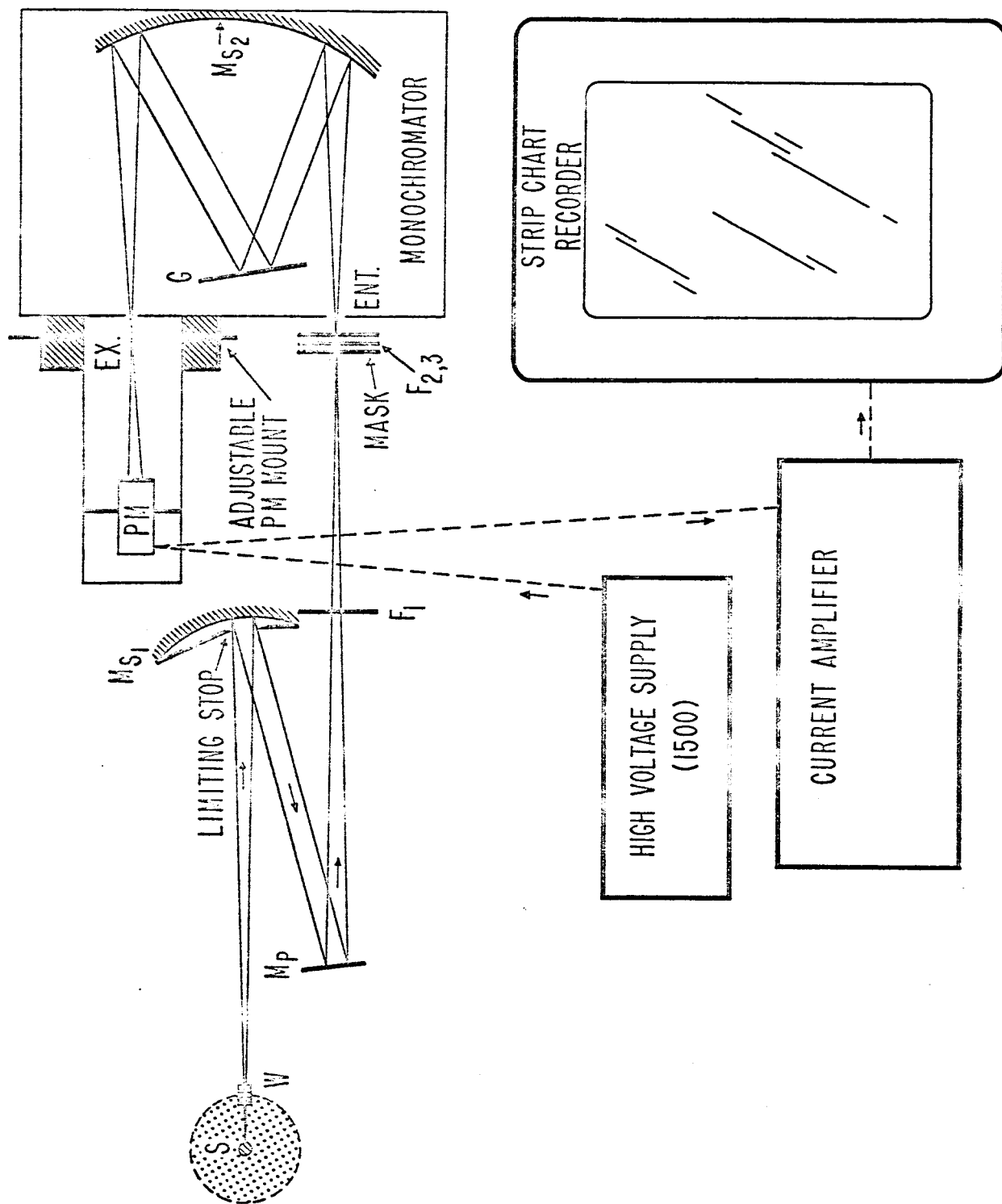


Fig. 5 Schematic diagram for the optical-electronic system for spectral radiance measurements. S is the source and W is the water-cooled quartz window. The location of the mirrors M , filters F , grating G , and photomultiplier PM is indicated.

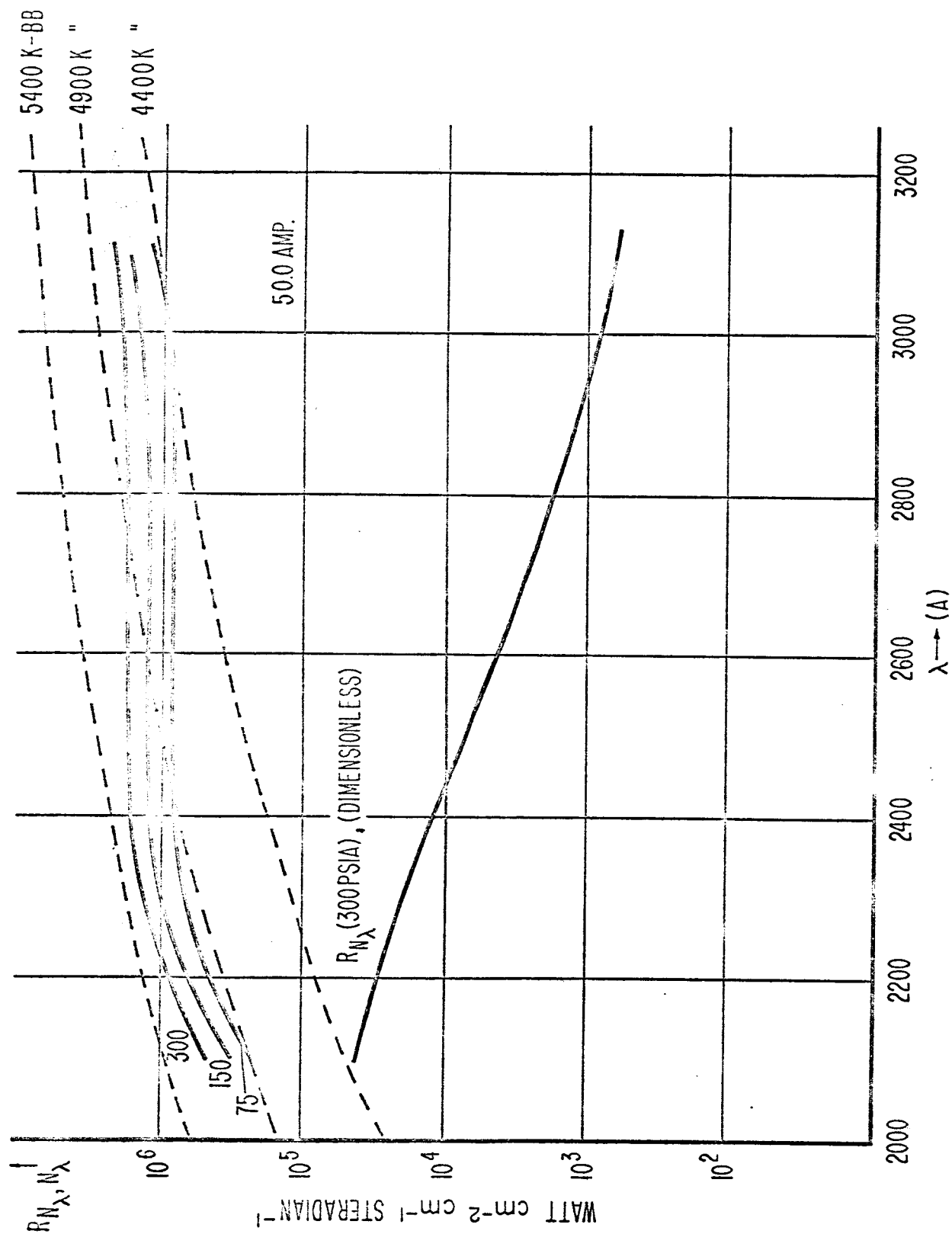


Fig. 6 High pressure argon spectral radiance for a 50 ampere arc. The lower curve is the spectral radiance ratio of the arc to the strip lamp.

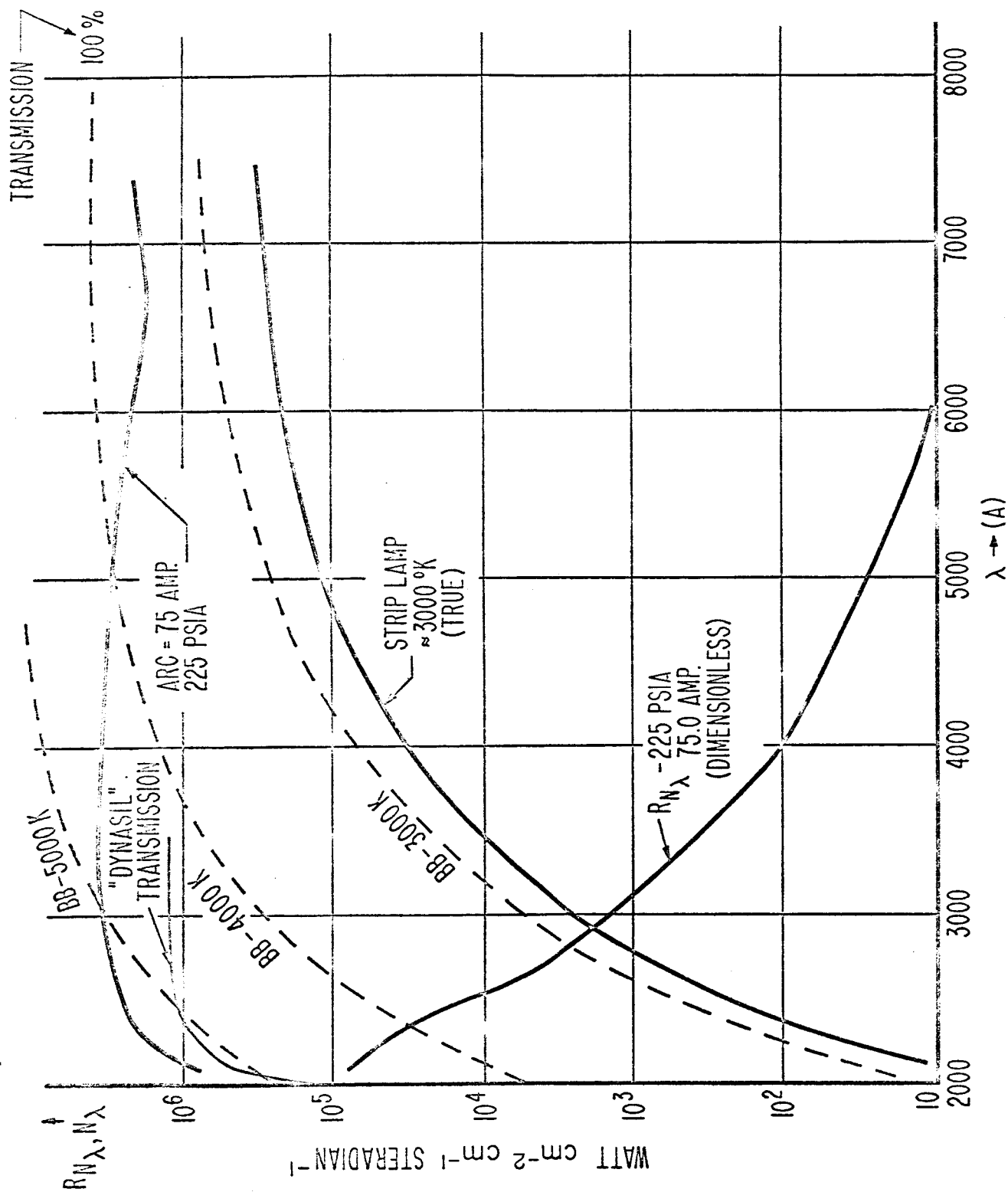


Fig. 7 High pressure argon spectral radiance for a 75 ampere arc. The lower curve is the spectral radiance ratio of the arc to the strip lamp.

APPENDIX B

A New High Accuracy Spectroradiometer

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A new Spectroradiometer for the calibration of spectral radiance standards has been developed at the NBS Institute for Basic Standards. The accuracy of spectral radiance calibrations has been inferior to that of almost any other widely used physical quantity, e.g. about 3% at 8500 Å and 8% at 2500 Å. The new Spectroradiometer achieves about a five-fold improvement in accuracy in the 8500 Å to 2500 Å region and extends the calibration range down to 2000 Å. The instrument is capable of an estimated accuracy of 0.3% at 6500 Å and 1.5% at 2100 Å. Continuing efforts are being directed towards standardization of the calibration procedure, extension of the wavelength range to 2.5μ, and the application of the methods to various types of tungsten strip lamps and the low current carbon arc.

The Spectroradiometer consists of a double monochromator with a photomultiplier detector and associated electronics, a stable high temperature blackbody, and a set of auxiliary sources used to determine the blackbody's temperature. The auxiliary sources include another blackbody maintained at the freezing temperature of gold (the gold point blackbody), a vacuum tungsten strip lamp, and a multiple beam splitter device. All sources are mounted on a motor-driven lathe, allowing rapid

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and precise positioning of each image on the monochromator slit. When the temperature of the high temperature blackbody is known, its absolute spectral radiance at any wavelength is given by Planck's radiation law. The spectral radiance of a source to be calibrated is then determined by direct comparison with the blackbody at each desired wavelength.

Various factors contribute to the improvements in range and accuracy. The extension of the calibration range to $2000\text{ }^{\circ}\text{A}$ is due primarily to the ability of the blackbody to operate routinely up to $2700\text{ }^{\circ}\text{C}$. The improved accuracy of the calibration is due to the high accuracy of the blackbody temperature measurement, the stability of the blackbody between these measurements, the quality of the blackbody (i.e. the emissivity), and to the stress placed upon such factors as source positioning and orientation, polarization, and current control and measurement. Probably the most significant of these factors is the more accurate temperature determination, wherein the monochromator, with the auxiliary sources, serves as a photoelectric optical pyrometer.

Temperature Measuring Technique

The temperature of the blackbody is determined by comparing its radiation, attenuated by a set of calibrated filters, to that from a highly stable vacuum tungsten strip lamp. Tables of blackbody temperature versus lamp current, as derived from the primary calibration of filters and lamp relative to the International Practical Temperature Scale (IPTS), yield the required temperature. All temperatures are measured at the wavelength $6545.7\text{ }^{\circ}\text{A}$, the location of a convenient standard spectral line. This wavelength region was chosen to facilitate intra-laboratory checks against the NBS photoelectric optical

Pyrometer.

The primary calibration procedure (at $6545.7 \text{ }^{\circ}\text{A}$) is almost identical to that applied to a photoelectronic optical pyrometer, except that the narrow bandpass ($24 \text{ }^{\circ}\text{A}$) of the Spectroradiometer results in an effective wavelength almost independent of source temperature. The current in the vacuum lamp is adjusted to make its spectral radiance equal to that of the high quality gold point blackbody, and the lamp current is measured. A small correction due to scattering and diffraction is made, because the sources are not the same size. For further lamp current versus blackbody temperature points, the multiple beam splitter, or beam combiner, is used, consisting of three stable sources (vacuum lamps) and two beam splitters. Each beam splitter is so oriented as to transmit part of the radiation from one source while reflecting a part of the radiation from a second source along the same path. The output of the first beam splitter, consisting of light transmitted from the first source and reflected from the second, is transmitted through the second splitter where it is combined with the reflected radiation from the third source to comprise the final output beam. Each source may be shuttered so that the output may be due to a single source or the sum of two or three sources. Thus the output of each of the three sources may be made equal to that of some external lamp and then combined to produce an output of twice or thrice the level of the lamp. Alternatively, the sum of the outputs of the three sources may be made equal to that of the external lamp, and simultaneously equal to each other,

resulting in available outputs from one or two sources that are one third or two thirds that of the lamp. Each new value transferred to the external lamp gives a new starting point from which to repeat the above procedure. If the external lamp was the vacuum lamp which had been matched to the gold point blackbody, then all these fractional and integral multiples of its initial value are multiples of the gold point radiation, i.e., of the radiation from a blackbody at a temperature of 1063 °C. The blackbody temperatures required to produce each of these multiples at 6545.7 Å are obtained from Planck's law. These temperatures and the associated currents are used to determine the coefficients in an equation relating the blackbody temperature of the lamp and its current. This equation constitutes a low range calibration of the vacuum lamp. The blackbody temperature of the vacuum lamp is limited to about 1350 °C, since at higher temperatures the lamp stability is impaired.

A set of special filters are used to extend the primary calibration to the higher temperatures required. These filters are composed of two filter materials of opposite temperature coefficients of transmission, with relative thicknesses chosen to cancel the heating effect. The transmittance of each filter is determined by means of the low range calibration on the vacuum lamp. A set of such filters is then used to reduce the spectral radiance of the blackbody to match that of the vacuum lamp. The ratio of spectral radiances is given by the product of the transmittances, with corrections for interfacial reflections.

This ratio, together with the lamp calibration, yields the temperature of the blackbody through Planck's law.

Stability and Quality of the Blackbody

The high temperature blackbody used in the comparison is a resistively heated graphite cylinder with a small hole drilled in the wall at right angles to the cylinder axis. The temperature of the blackbody is continuously variable up to about 2700 °C and is determined by the spectroradiometer at 6545.7 Å before and after comparison with the test source.

In order to maintain a nearly constant temperature of the blackbody over the time period between temperature measurements, a radiation control device is employed. The output of a phototube which senses the radiation from a rear wall of the cylinder is balanced against the output of a stable, variable battery supply, which serves to set the desired level. Any imbalance in the resulting signal is amplified and fed to a saturable reactor-transformer combination supplying the blackbody current, and this current is thereby altered until the phototube output again matches the battery output. Repeated measurements have shown a stability of 0.1% in spectral radiance over the time period between temperature measurements (about 20 min.).

The blackbody quality of a cavity depends mainly on the temperature uniformity of the cavity walls, the solid angle subtended at the sighting area by any holes in the cavity, and the emissivity and

surface condition (partial reflectance) of the wall material. By properly shaping the graphite tube and the use of sufficient radiation shields, a temperature uniformity in the main cavity of about 10 °C at high temperatures has been obtained. The ratio of cavity depth to hole radius is about 13 for the 2 mm hole currently employed. The use of graphite insures a high emissivity, and the machine threading of the inner cavity wall reduces the partial reflectance. With these precautions, an estimated cavity emissivity of 0.999 has been achieved.

Details of the Apparatus

Strip lamps generally exhibit a variation in spectral radiance with angular and translational orientation, requiring high precision in positioning them if repeatable measurements are needed. These requirements can be relaxed somewhat if regions of zero gradient ("flat regions") are located. Although relatively free of gradients, the blackbodies must also be carefully oriented, so that some part of the blackbody is not the aperture stop of the system. In order to locate these flat regions, and to reposition the sources precisely, a means of making and observing fine motions is necessary. Each source is affixed to a double-gimbel mount having six degrees of freedom with a setting sensitivity of 0.001 inches in translation and 0.1 degrees in angular motion. The lamps are fabricated with a small notch in the filament which serves as a reference mark along the filament length and a small arrow is etched in the rear of the envelope to determine the orientation with respect to the optic axis.

A high power telescope is used to help orient and set the source image on a graduated slit mask.

The double monochromator is a quartz prism-grating instrument, chosen for its low scattered light and adequate wavelength accuracy. The photomultiplier has a tri-alkali cathode with a quartz window. Two calcium fluorite plates are located at the exit slit to depolarize the instrument at one wavelength, so that the polarization properties of the sources may be minimized and measured. Currents for the lamps are provided by highly stabilized DC power supplies capable of maintaining the current steady to about 0.003% over a period of about ten minutes and 0.01% over much longer periods. The currents are measured by a six-dial potentiometer reading the potential drop across a stable calibrated resistor. The uncertainty of the current determination is less than $\pm 0.003\%$.

The best estimate of the present accuracy of the new Spectroradiometer yields uncertainties of 1.5% at 2100 A, 1.2% at 2500 A, and 0.9% at 3000 A, decreasing to 0.3% in the region 6500 to 8500 A. The standard deviation of a single determination at each wavelength is about one fifth that of the stated uncertainties. Measurements performed on a number of gas filled tungsten strip lamps indicate that lamp calibration uncertainties within a factor of two of the stated instrument uncertainties are possible.

Present efforts are being directed towards standardizing the methods used, determining the spectral radiance of the low current

carbon arc, and extending the use of the instrument to 2.5μ . In order to complete this work as soon as possible only a limited number of special calibrations are being offered at this time. Priority will be given to those requiring calibrations below 2500 A and to those whose research problems exhibit a need for greater accuracy in spectral radiance than is available commercially (about 5%). Those parties requiring such calibrations are invited to contact Dr. H. J. Kostkowski of the Temperature Physics Section.